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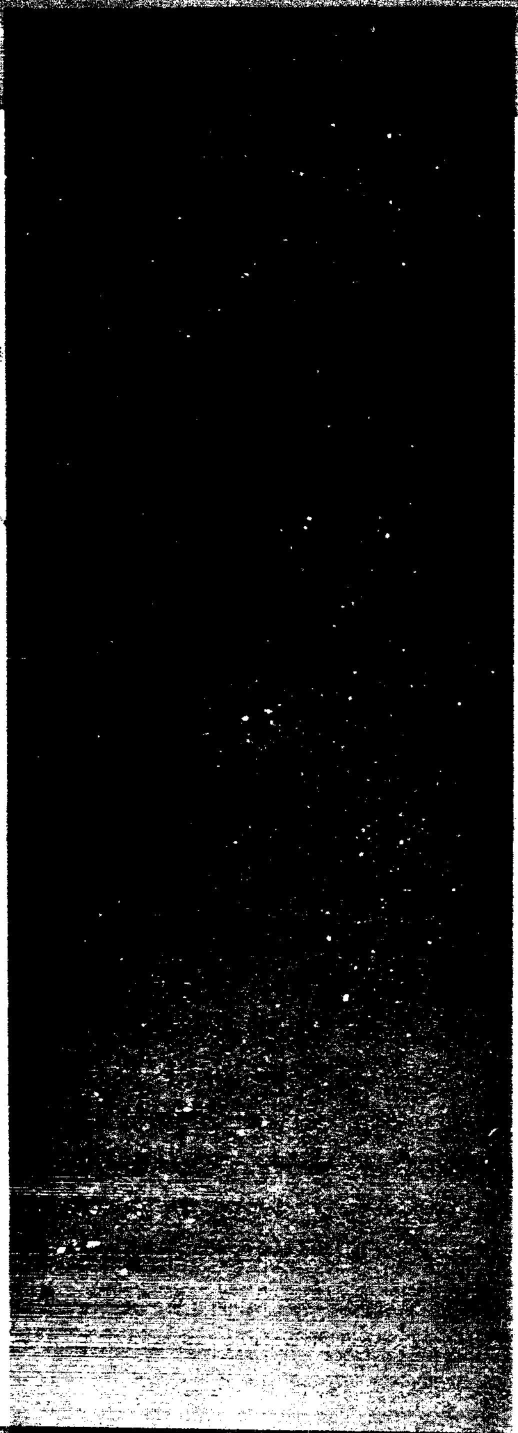


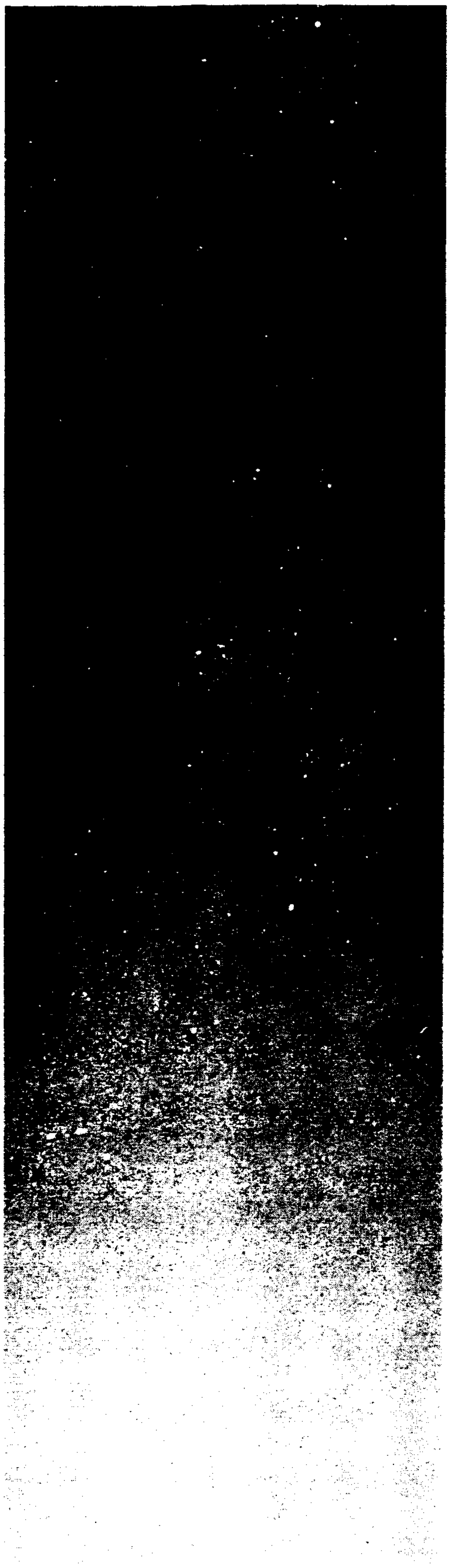
SUNFLOWER POWER CONVERSION SYSTEM

QUARTERLY REPORT

JUNE – AUGUST 1962

TAPCO a division of
Thompson Ramo Wooldridge Inc.

ER-5044



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I. PROJECT OBJECTIVES

The Sunflower program objectives are to accomplish design, fabrication, test and development tasks oriented toward confirming the conceptual validity and performance feasibility of a solar-powered 3 kw mercury Rankine power conversion system.

Major items include solution to long-term, high temperature lithium hydride containment, demonstration of component operational and endurance integrity (especially of the turbo-alternator), experimental confirmation of the design integrity of the aluminum honeycomb petaline collector, and operational integrity of the integrated Rankine system.

II. PROJECT OBJECTIVES FOR THE REPORTING PERIOD OF JUNE 1, 1962 THROUGH SEPTEMBER 1, 1962

Negotiations will continue to finalize the program objectives. As the schedule now exists, the major subtasks of this quarter are as follows:

Continue developmental testing of CSU I-3 to determine performance data and operational integrity.

Complete assembly of PCS I-1 and initiate system checkout and testing.

Complete the fabrication of the full paraboloid collector and initiate optical testing.

Publish topical reports on the rotational speed control development program and the boiler/heat storage development program.

Complete the workhorse loop. Begin checkout of the loop and initiate loop operation.

Complete the 2500-hour solarmic Haynes 25 and aluminized Haynes capsule test. Complete the analysis of capsules from test No. H-7, ST-7, ST-8, ST-9, ST-10 and ST-12.

Continue the investigation of hydrogen permeability using the two test rigs which are now in operation.

Attempt to fabricate laminated metal-glass-metal tubes with solarmic glass centers and Haynes 25 walls.

III. PROJECT PROGRESS DURING THE REPORTING PERIOD

PROJECT MANAGEMENT

During the reporting period, discussions with NASA continued regarding redirection of the Sunflower program. Scope of the current program will be to conduct basic research and development work directed toward solution of the problems associated with the development of a solar mercury Rankine system with reliable endurance capability. Specifically, analytical and experimental efforts will be conducted during long-term operation of components and the system to define and correct failure modes and to confirm capability of the system for corrosion resistance, hydrogen containment, and lithium hydride containment.

Other project management efforts included the development of test plans and objectives necessary for the component and system testing that was conducted during the reporting period. Considerable effort was also consumed in the supervision and direction of the CSU I-3 turbo-alternator test which continued throughout the entire quarter.

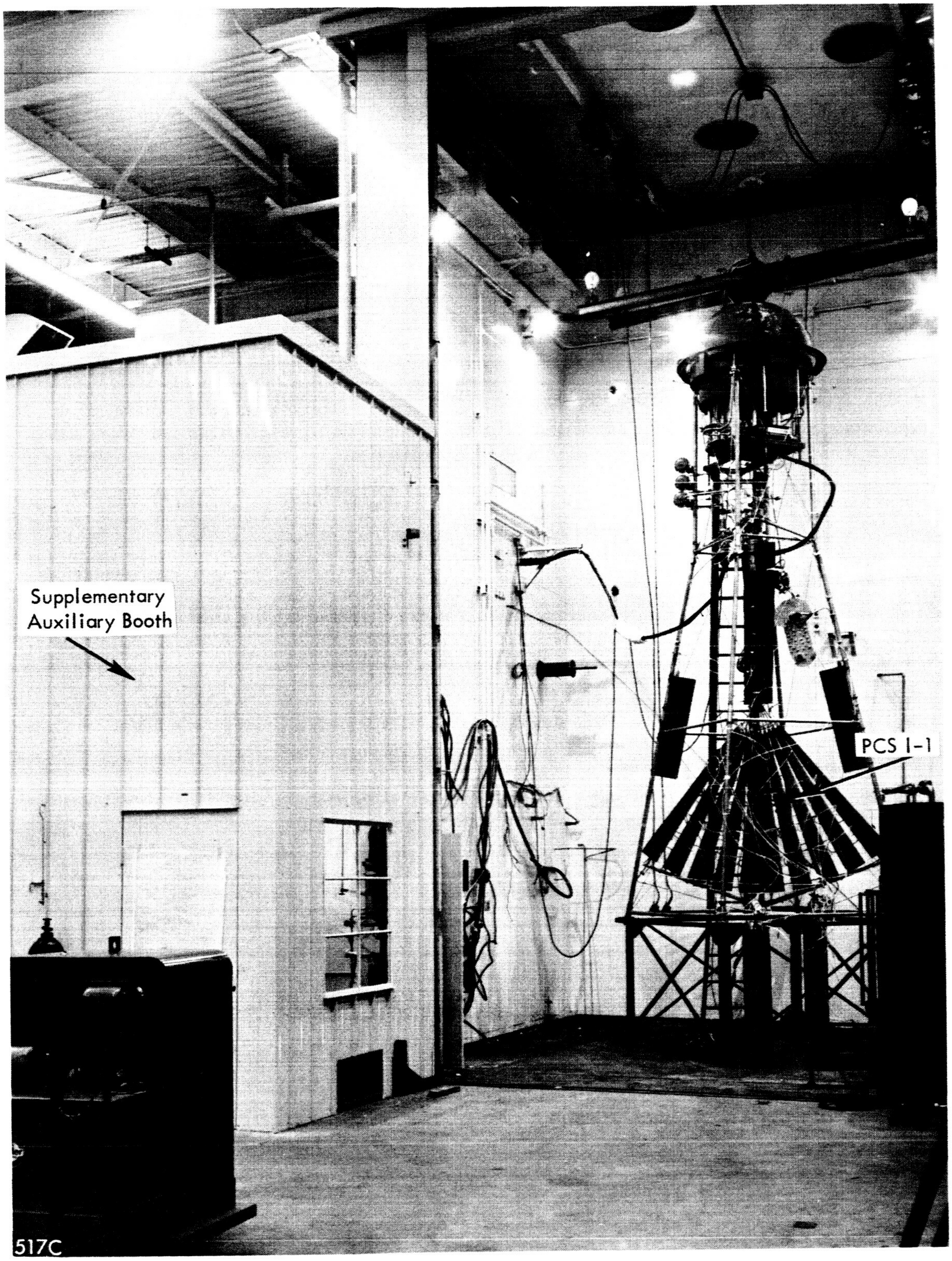
TEST RIG DESIGN AND FABRICATION

As reported in ER-4925, installation of the auxiliary equipment required for system operation had been delayed pending completion of the CSU I-3 test. To expedite system testing, the auxiliary enclosure shown in Figure 1 was constructed. Final installation work is in progress for the auxiliary equipment required for system support.

During the reporting period the component test rig was operated in support of the turbo-alternator performance and endurance test. The rig was operated continuously for 2348 hours in support of this test. Several minor rig difficulties were encountered throughout the test, but the malfunctions which occurred did not affect the operation of the CSU. The notable malfunctions which occurred in the test rig include the following:

1. loss of control of the turbine inlet throttling valve,
2. failure of the bellows seal in the rig superheater bypass valve,
3. malfunction of a portion of the guard heaters on the superheater,
4. leakage in a water-to-mercury heat exchanger,
5. loss of several thermocouples on the superheater,
6. shorting of a wattmeter.

As mentioned, none of the malfunctions was so serious that the operation of the CSU was stopped. Rig modifications were made during continuous operation of the CSU to correct these malfunctions.



SYSTEMS TEST RIG

FIGURE 1

Initial installation work in the systems test rig was started during the last week of this quarter. Present plans include installing the PCS I-1 in the test rig and performing a system flushing and preconditioning operation on the plumbing prior to installation of the turbo-alternator unit in the system. In addition to flushing and preconditioning the system plumbing, corrosion product separators will be installed in an effort to trap a large percentage of the corrosion products that are formed. This particular operation is important; the results of the CSU I-3 test have indicated corrosion product deposition is the direct cause of CSU I-3 shutdown.

POWER CONVERSION SYSTEM

All assembly work for PCS I-1 has been completed and the unit is ready for installation into the test rig. Figure 1 shows PCS I-1 in the system test rig, being readied for system flushing and preconditioning. The turbo-alternator unit to be incorporated in this system will undergo a component checkout in the component rig prior to installation in the system.

It should be recalled that the PCS I-1 system is fabricated primarily from Type 316 stainless steel. For this reason, and in light of the results of the recent CSU test, efforts are being made to precondition the system and to incorporate corrosion product separators in the system in an attempt to eliminate the problem which developed in the CSU I-3 nozzles. Short-term performance testing, not necessarily long-time endurance testing, was the original objective of the PCS I-1 system.

PCS I-1 is described as a preprototype system in that all components fit their respective package envelope and the assembly should operate completely independently from test rig auxiliaries. Exceptions to this capability are relatively minor and consist primarily of the following details:

1. An auxiliary mercury pump is connected to the system in a manner permitting:

    a. prestart bearing flow calibrations,

    b. inventory circulation during startup

    c. inventory addition or removal during operation,

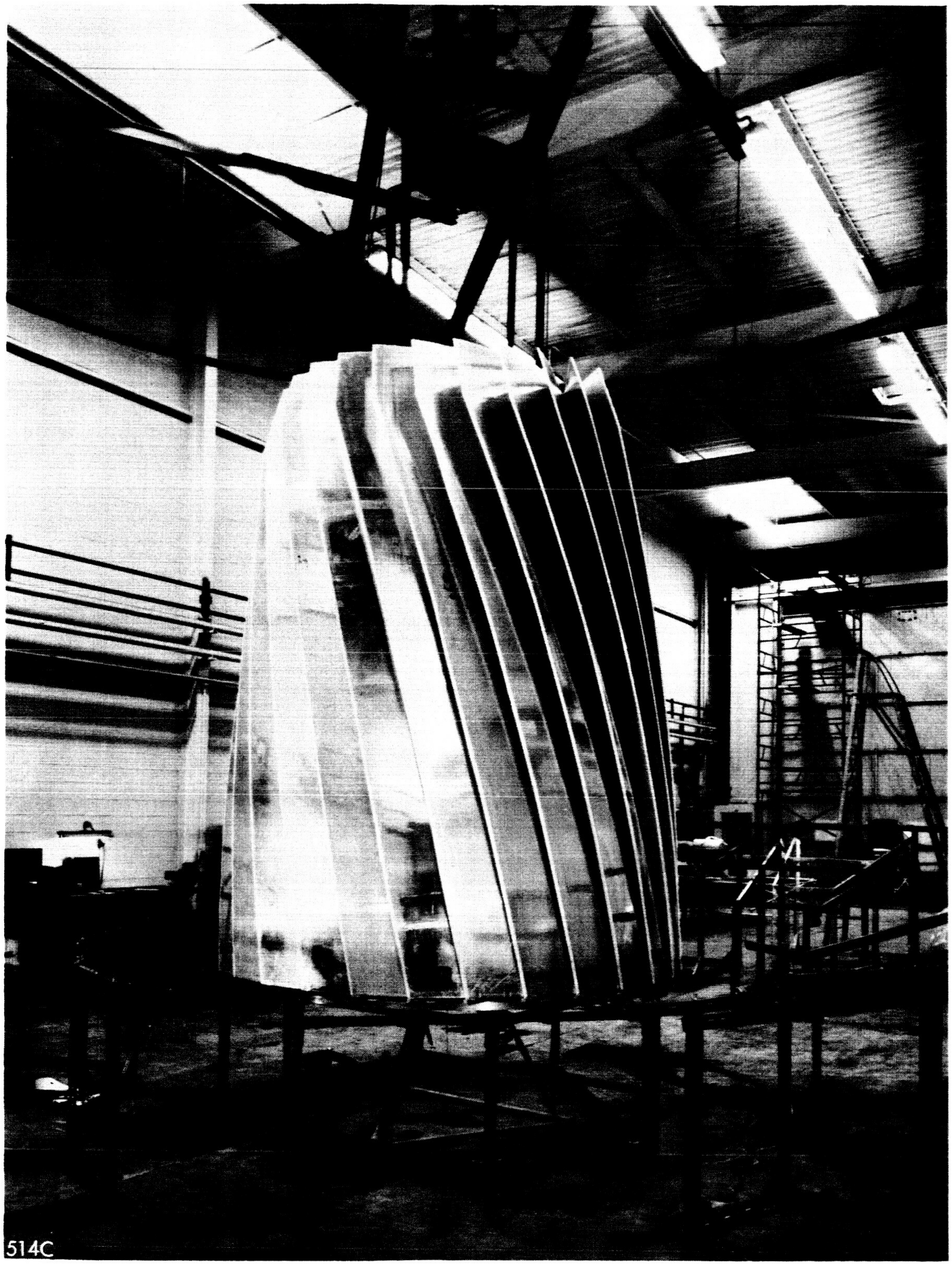
    d. backup for the turbo-alternator package pump during operation and

    e. system flushing and preconditioning.

2. Gravity is employed to maintain a stable interface above a condensate inlet.

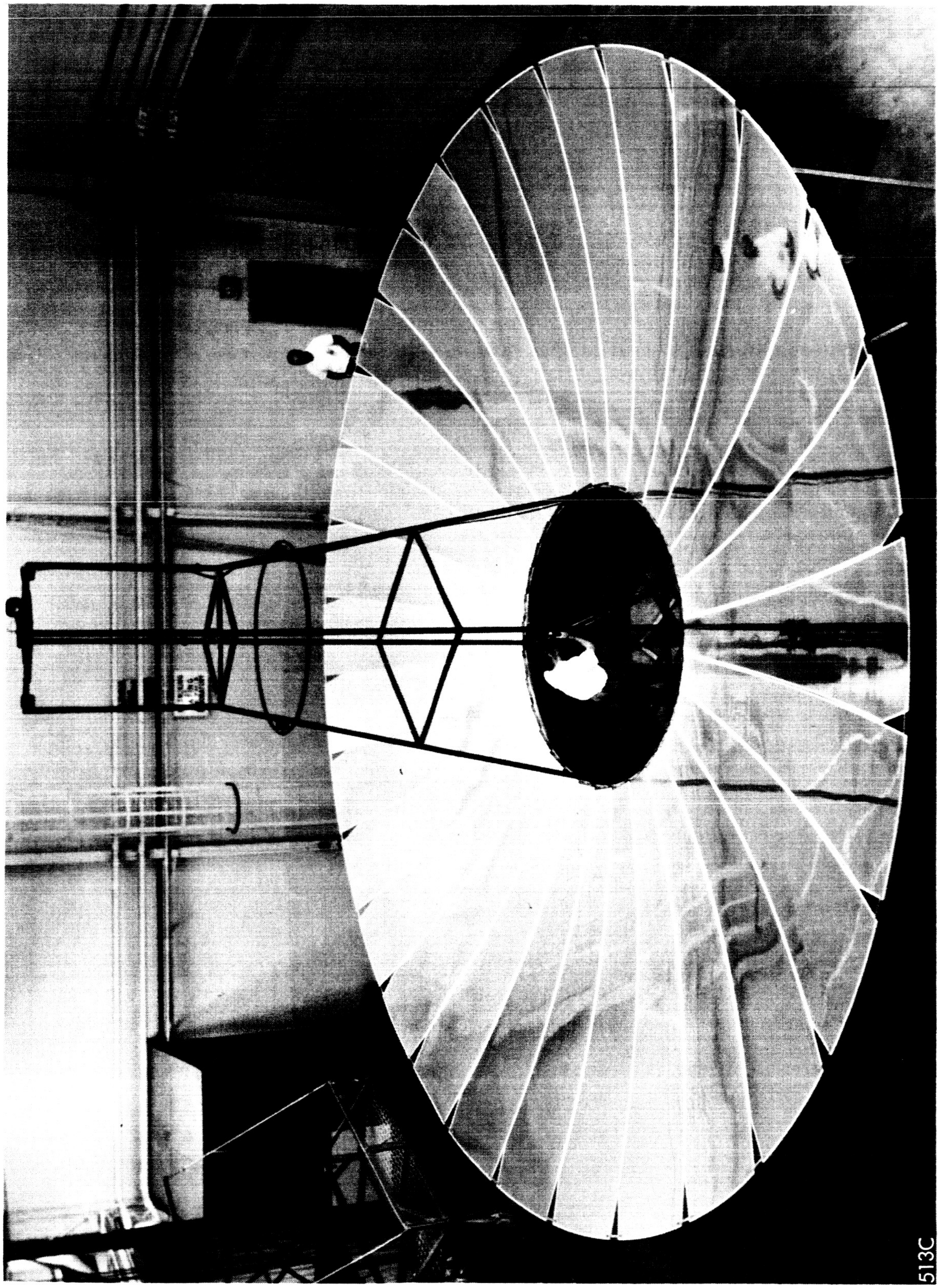
SOLAR COLLECTOR

The full-scale preprototype solar collector has been fabricated and assembled. Figures 2, 3 and 4 shows the solar collector in the stowed position with a simulated structure and in the deployed position.



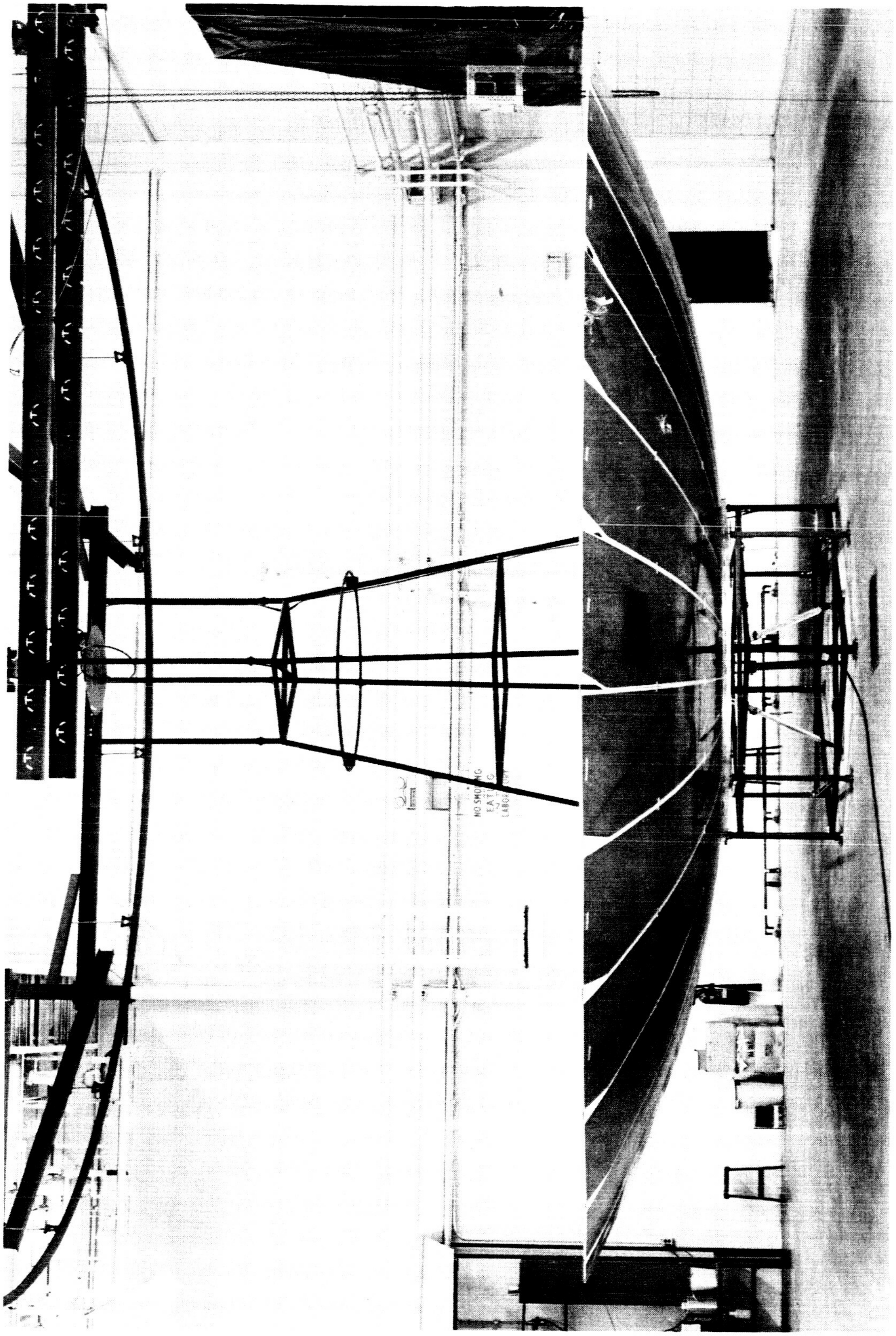
PREPROTOTYPE COLLECTOR STOWED

FIGURE 2



PREPROTOTYPE COLLECTOR OPEN (FRONT VIEW)

FIGURE 3



PREPROTOTYPE COLLECTOR OPEN (SIDE VIEW)

FIGURE 4

The collector was assembled on the optical test rig without the prototype rim locking hardware. Simple straps were utilized in place of this hardware until the prototype hardware was received from fabrication.

The first test conducted on the paraboloid consisted of an optical scanning of the collector using the shadow box and photographic equipment. The principle of the photographic equipment is that a light source placed at the focal point of the parabola will reflect collimated light from a true parabolic shape. The collector is traversed with the separated grid surfaces; any deviation of the collector surface causes a shadow effect on the upper grid which can be analyzed for surface error. This method allows rapid inspection of large areas.

Ground supports were removed from the collector and the influence of 1 g was mapped using the optical scanning equipment. This mapping will be used as a reference for all future collector development testing. The results of the initial tests indicated that the deflections of the petals at the mid-span are sufficiently large under the 1 g environment to require mid-span locks. The panels were modified to include the mid-span locks and a new reference map was completed for the collector. This modification was also indicated by the results of the computer structural analysis to achieve required freedom from thermal distortion.

The collector was then stowed as shown in Figure 2 and was removed from the optical test rig in preparation for closed vibration testing. The vibration fixture for this testing has been completed and is shown in Figure 5. Initial tests conducted on the fixture show that it has an unloaded natural frequency of approximately 360 cps and that some points will exist in the vibration spectrum where fixture decoupling may occur. This phenomenon will be investigated as the testing progresses.

The complete collector, fixture, and simulated structure were assembled on the C-210 vibration excitor as shown in Figure 6. Initial work involving the installation of bungee supporting cords, instrumentation, and calibration equipment has been started. Initial low-level surveys are to be run of the 20 to 2000 cps spectrum to determine natural frequencies and cross-axis vibration that may be encountered in the simulated structure.

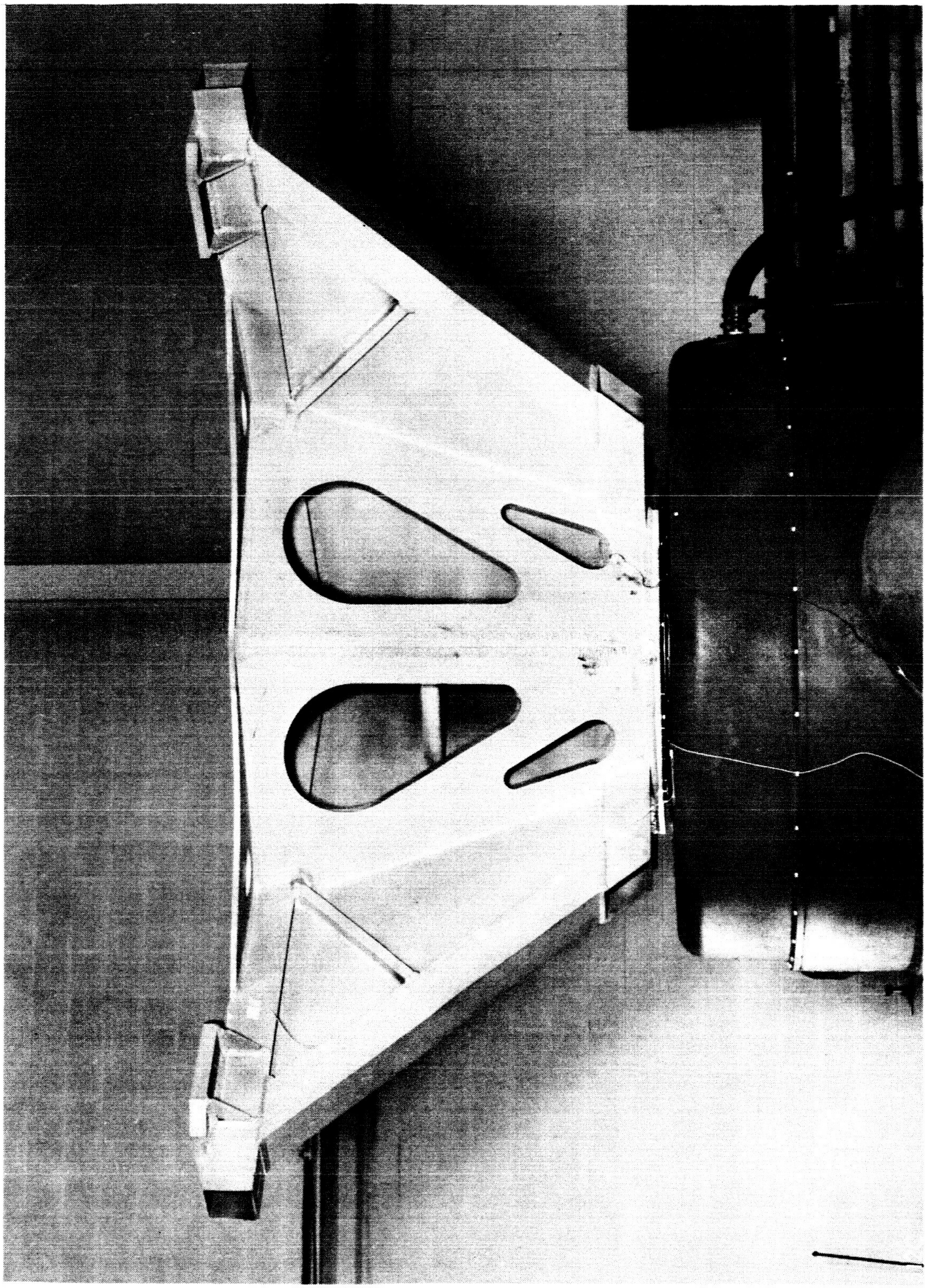
Other single panels of the full-scale collector have been fabricated, and include the lacquer, aluminum deposition, and silicon oxide finishes. These panels will be used for forthcoming single panel testing to determine petal efficiencies when using a water-cooled calorimeter.

TURBO-ALTERNATOR UNIT

As reported in the March-May 1962 quarterly report, the CSU I-3 turbo-alternator test was initiated on May 23, 1962. The hardware had the following significant deviations from design:

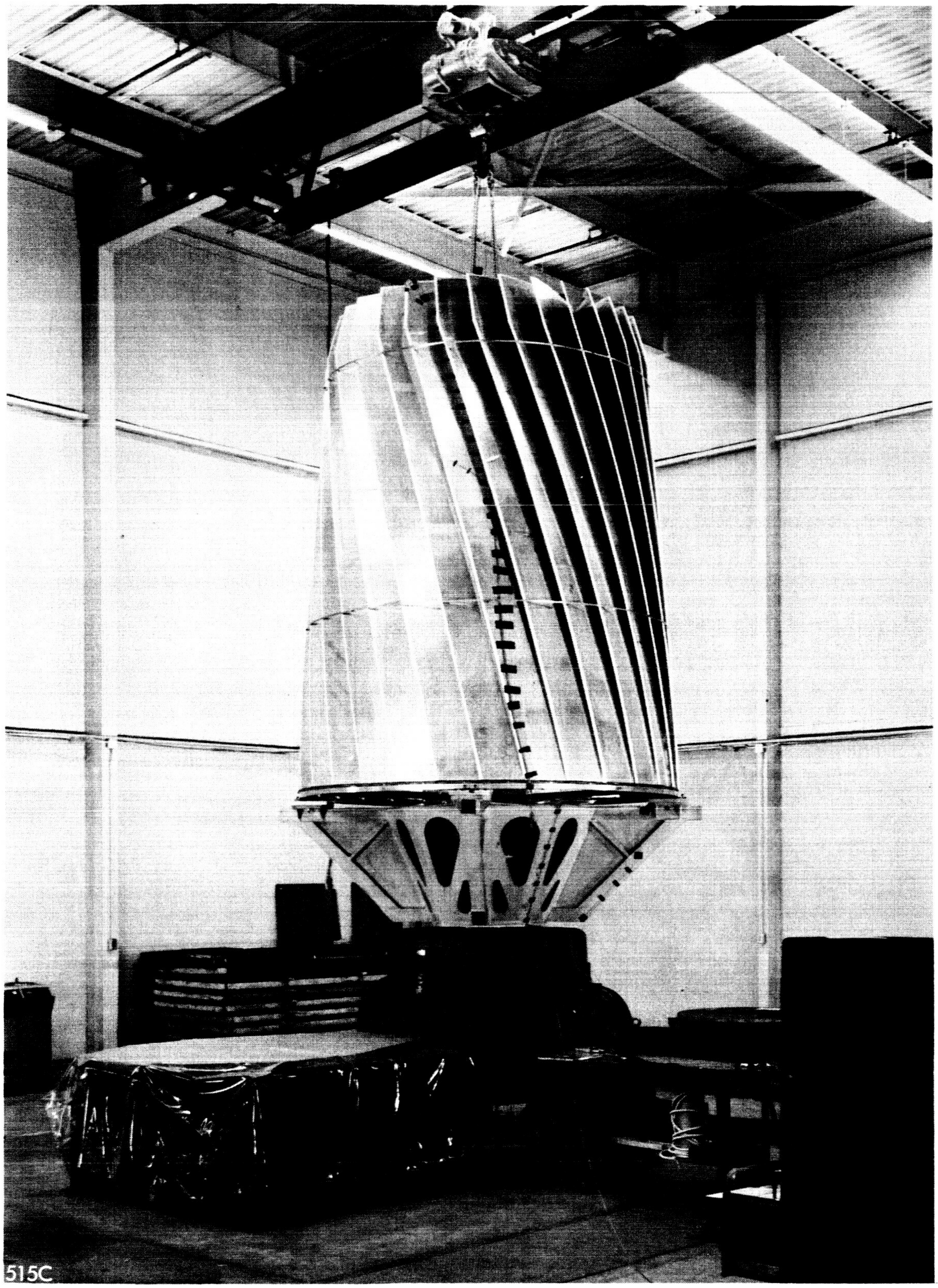
1. The second stage labyrinth seal clearance was 0.0001 inch large radially.

2. A cold gas nozzle test revealed a first stage nozzle throat area to be 5% under design.



SUNFLOWER COLLECTOR VIBRATION TEST FIXTURE

FIGURE 5



COLLECTOR VIBRATION TEST INSTALLATION

FIGURE 6

3. The third stage nozzle throat area was approximately 17% large.

The speed was brought up to 20,000 rpm manually and then was switched to the automatic rotational speed control; 20,000 rpm was maintained for 2.5 hours during which time bearing, turbine, and alternator performances were found to be excellent. The speed was increased in 5,000 rpm increments to 40,000 rpm within a time period of approximately eight hours. After one hour of operation at 40,000 rpm, the speed was reduced to 35,000 rpm for the first 500 hours of operation. The speed was reduced during this time because an analysis made prior to the initiation of test indicated a possible creep stress problem in the alternator rotor sleeve at design speed and temperatures. A re-evaluation of this analysis failed to support this conclusion, and after 500 hours the speed was increased to 40,000 rpm. During the succeeding hours of testing, design performance and off-design performance operations were conducted on the unit at constant speed of 40,000 rpm.

A performance evaluation of the CSU I-3 is shown in Figure 7. The test data are a statistical average of reduced data at design inlet and exhaust conditions at 40,000 rpm and are representative of turbine performance at design conditions. The 2925 watts delivered power from the alternator is less than a design value of 3500 watts but can be accounted for by the previously noted turbine nozzle area deviations. Thus, the combined efficiency of the packaged components is very near design values.

At approximately 1360 hours of total operation a decay in alternator output power was noted with no apparent change in the input conditions. This decrease in power continued at a rate of 50 watts per day. It was also noted that mercury flow to the turbine was decreasing as shown by flow measuring devices in the test rig and, correspondingly, the heat input to the rig boiler had to be decreased to maintain constant inlet temperature conditions. The difficulties which were encountered were judged to be caused by corrosion product deposition on the first stage turbine inlet nozzle. The following attempts were made to stop the decay of power:

1. Turbine inlet pressure was increased.

2. Turbine inlet temperature was increased.

3. Turbine inlet pressure was decreased.

4. The test rig mercury was diluted by displacement of 1200 pounds of mercury in the rig.

5. The turbine inlet temperature was cycled between 1190 and 1265°F.

The power continued to decrease until it recorded a level of approximately 1400 watts at 1768 hours. At this time items 4 and 5 above had just been effected, and the power decrease stopped. The unit then established a power output of approximately 1500 watts with a turbine inlet pressure of 225 psia (a result of item 3) as compared to the design value of 240 psia.

SUNFLOWER TURBOALTERNATOR PERFORMANCE

PARAMETER		OPERATING CONDITIONS DESIGN POINT	TEST DATA
SPEED	(RPM)	40000	40000
TURB. INLET PRESSURE	(PSIA)	240	240
TURB. INLET TEMPERATURE	(°F)	1250	1250
TURB. EXH. PRESSURE	(PSIA)	7.0	7.0
TURBINE FLOW RATE	(PPm)	13.7	13.0
ALTERNATOR OUTPUT	(WATTS)	3500	2925

FLOW CORRECTION (1ST STAGE NOZZLE)

$2925 \times \frac{13.7}{13.0} =$ 3082 WATTS

TURBINE SHAFT POWER CORRECTION
(3rd STAGE NOZZLE)

$200 \times .87 =$ 174

ESTIMATED CORRECTION POWER 3256

UNACCOUNTABLE (3500-3256) = 244 WATTS

TURBINE SHAFT POWER
BEARING POWER
SEAL POWER
PUMP POWER
ALTERNATOR EFFICIENCY
INSTRUMENT ERRORS

} SOURCES OF UNACCOUNTABLE POWER 244 WATTS

FIGURE 7

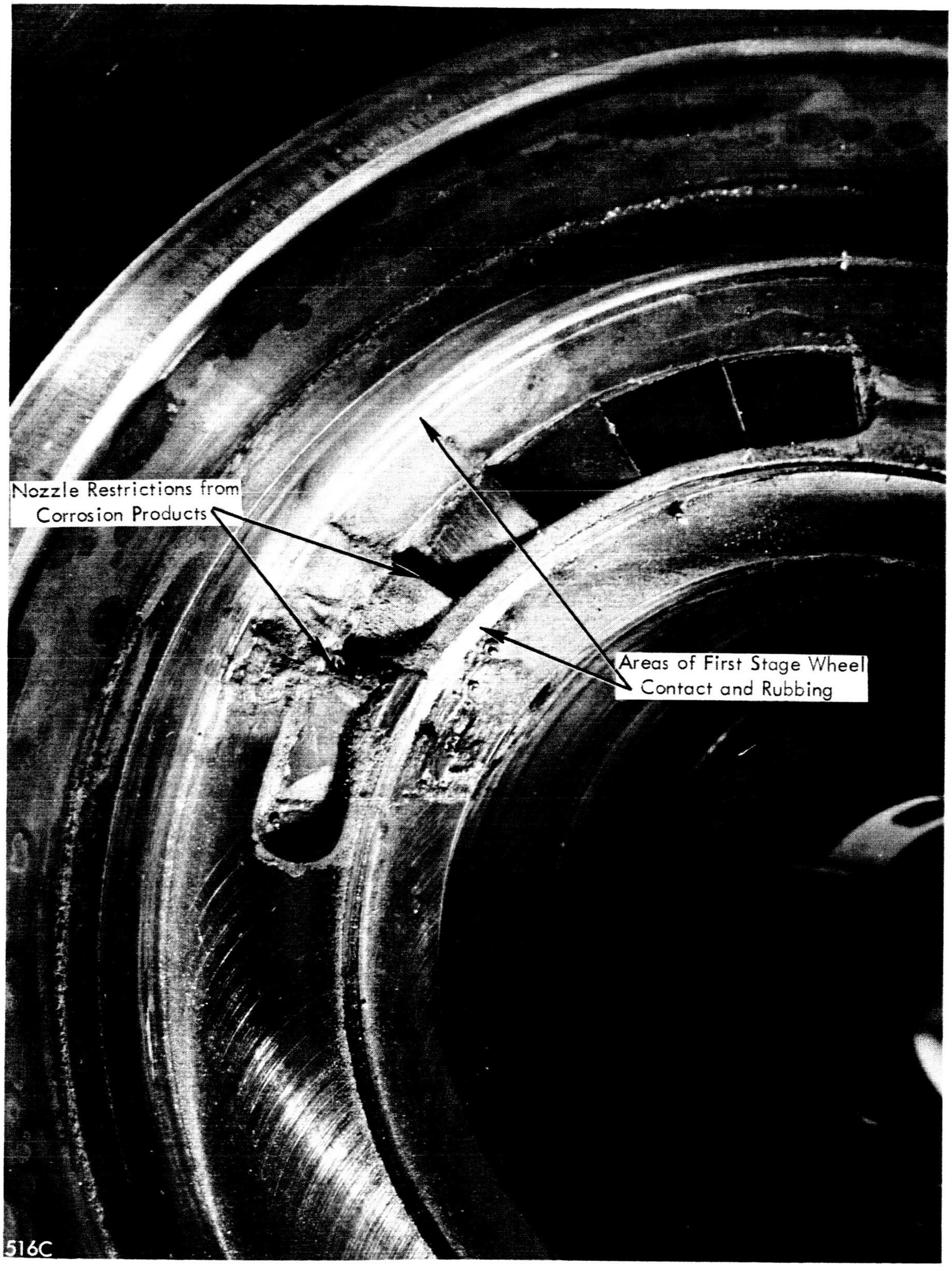
The unit continued operation at a power level of approximately 1500 watts with no further reduction until a total time of 2348 hours had elapsed. At this time a seizure of the unit occurred and the test was terminated on August 29, 1962. Post-test inspection of the hardware has confirmed the earlier suspicion of corrosion product deposition in the first stage nozzle as shown in Figure 8. In fact, the corrosion product formation is solely responsible for stoppage of the unit.

Although the above test results are quite preliminary, the apparent cause of failure is corrosion product deposit accumulation in the first stage inlet nozzle growing into the clearance space between the first stage nozzle exit and the turbine wheel. There exists evidence on both the wheel and nozzle housings of rubbing of the turbine intermediate ring and shrink ring with the corrosion products.

Bearing performance throughout the entire run was extremely satisfying. As long as the package conditions were maintained constant, the bearing flow and pressure remained unchanged. During the post-test inspection of the components, the physical dimensions of the journal bearings and bushings were checked. The results of this test indicated no dimensional changes in either journal bearings or bushings, measured to an accuracy of 0.0001 inch. The unit has not been completely disassembled; however, visual observations of the thrust bearing, thrust washer, and thrust face on the shaft indicate that the thrust bearing is also in excellent condition. The spiral grooves of the thrust bearing have a nominal depth of 3 to 5/10,000 of an inch and remain plainly visible, indicating that no significant wear has occurred.

The only other area in which deterioration of performance was noted was in the operating performance of the package pump. During the test the jet nozzle of the jet-centrifugal pump became obstructed by some foreign particle. This conclusion is based on the fact that the deterioration in performance appeared quite suddenly in the course of running a pump calibration test. A calibration of the output pressure versus flow of the pump was performed with the results predicted. However, with no interruption in operation a second calibration curve was being plotted when the pump performance suddenly changed and assumed the characteristics of a straight centrifugal pump without the jet pump supercharging. Subsequent operation of the pump was continued with no further deterioration of performance for the remainder of the test.

The preliminary results which have been observed during disassembly of this unit indicate that the basic design of the turbo-alternator unit is excellent. Emphasis must be placed on limiting corrosion product deposition from outside sources that affect the turbo-alternator unit. It should again be pointed out that this particular test limit (2348 hours) was due to the corrosion products formed by the test rig. The objectives and specifications for this rig as originally established were for component performance and checkout testing, not specifically endurance testing. An endurance test rig would be constructed of materials other than Type 316 stainless steel. Another factor that influences the quantity of corrosion product formed is the surface area exposed to liquid mercury. The test rig exposes a greater area than would be exposed in an actual power conversion system assembly.



CSU I-3 TURBO-ALTERNATOR FIRST STAGE NOZZLE
CORROSION PRODUCT DEPOSITION

FIGURE 8

Results of this test indicate that continued long-term operation of turbo-alternator units in this test rig will require addition of corrosion product separators and possibly incorporation of centrifugal separators in the turbine inlet line. Another factor which should aid long-term testing is that the rate of corrosion product formation is dependent upon exposure to the mercury (see Figure 8). Since the test rig has accumulated in excess of 3000 hours of mercury operation the rate of corrosion product formation should be quite low, to the benefit of future long-term tests.

The following will be incorporated in turbo-alternator unit I-4:

1. The first stage nozzle will be modified to provide the proper throat areas.

2. A redesigned double-walled heat shield for the turbine bearing cavity will be used.

3. All labyrinth seal clearances will be at design values.

4. A coiled tube alternator coolant jacket will be incorporated in place of the manifold arrangement currently used.

5. Stiffening struts will be incorporated in the exhaust scroll to increase the stiffness of the housing.

6. The alternator cavity screw pump will be redesigned to provide a smooth shaft with the screw portion on the static housing; the reverse arrangement has been employed to date. This modification results from experimental data which confirms that the performance of the seal is significantly improved at 40,000 rpm when the threads are in the bore.

ROTATIONAL SPEED CONTROL

Rotational speed control activity under the present program scope has been completed. A topical report is in the final stages of review by TRW and NASA.

The breadboard speed control operated throughout the 2348-hour CSU I-3 test without malfunctions and performed its job faultlessly.

CONDENSER-SUBCOOLER

As reported in the previous quarterly report, condenser CSC-I-1A testing was completed during the last quarter. This component was designed for ground operation, relying on convection as well as radiation for heat rejection. Throughout the test, the condenser was oriented in the most adverse required operating condition, i.e., vapor flow in opposition to gravity.

Data reduction and analysis of the test results have shown that operation of the complete condenser unit (which includes the primary and secondary radiators, the interface, and compact heat exchangers) was achieved over vapor flow rates from 5.6 to 14.1 pounds per minute with qualities as low as 75.5%. (The weight flow data presented in the previous quarterly report, ER-4925, was in error. This was noted during data analysis.) The inlet pressure was varied between 4.8 to 18.5 psia and the condenser pressure drop varied from 3.7 to 9.4 psi. Vapor velocities were in the range of 45 to 173 feet per second. In each case, all of the incoming flow was delivered as condensate to the interface with no liquid hold-up in the condenser.

Two problem areas were noted during the condenser operation. One was a condenser operating pressure higher than design requirements. This has been traced to a high temperature drop between the tube temperature and fin temperature and possibly to a blanketing and/or reduction of area due to the condenser preheaters which are installed on the fins. The large temperature drop between the tube and fin may result from the resistance of the brazed joint. This is currently being investigated. The heaters utilized during this test are standard strip heaters and would not apply to flight-type hardware; as a result this problem should not occur in the prototype components. These factors reduce heat rejection capacity, causing the pressure to assume a level higher than design level. A second difficulty was a change in the condenser performance with operating time. The symptom was inability, after running time had been accumulated, to operate the condenser without experiencing minor slugging where earlier identical conditions had not incited slugging. The performance change is currently felt to result from a form of progressive wetting of the wall. A graphical presentation of the change in vapor velocity required to eliminate slugging is shown in Figure 9. Continued work is being directed toward this problem area. It should be noted that although slugging phenomena occurred, the condenser still operated and did deliver all flow to the interface chamber. No liquid inventory build-up in the condenser was experienced as had been noted in the original CSC-1 condenser test.

The operation of the condenser will affect PCS testing in that operation at the correct turbo-alternator discharge pressure requires that the system flow be reduced to approximately 10 pounds per minute. This will result in a decrease in power output but will allow operation of the system with all components. Alternatives to achieve higher power will require raising turbine inlet pressure or employing forced convection cooling of the radiator to achieve the correct weight flow.

LITHIUM HYDRIDE CONTAINMENT

A 2400-hour test with lithium hydride containment capsules has been completed. The capsules tested were fabricated from Haynes 25 which had been aluminum dipped and oxidized, aluminum chromalized and oxidized, and glass coated. The test incorporated a cycle consisting of two hours of temperature rise from 1165 to 1600°F, followed by a 24-hour soak at 1600°F and a 1.25-hour cooling cycle. The results of this test are shown in Tables 1 and 2. As was expected, the solaramic-coated Haynes 25 capsules contained a high percentage of lithium hydride after the test and the other coatings did not afford an appreciable barrier to the loss of hydrogen during a test. The performance of the solaramic barrier was, in fact, better than previous extrapolation has indicated.

MATERIALS

Preliminary results of the long-term static temperature tests are shown in Tables 3 and 4. In the hydrogen atmosphere furnace three samples were run for approximately 5,000 hours at a temperature of 1600°F.

PRIMARY CONDENSER VELOCITY REQUIREMENTS
TO AVOID SLUGGING VERSUS TIME

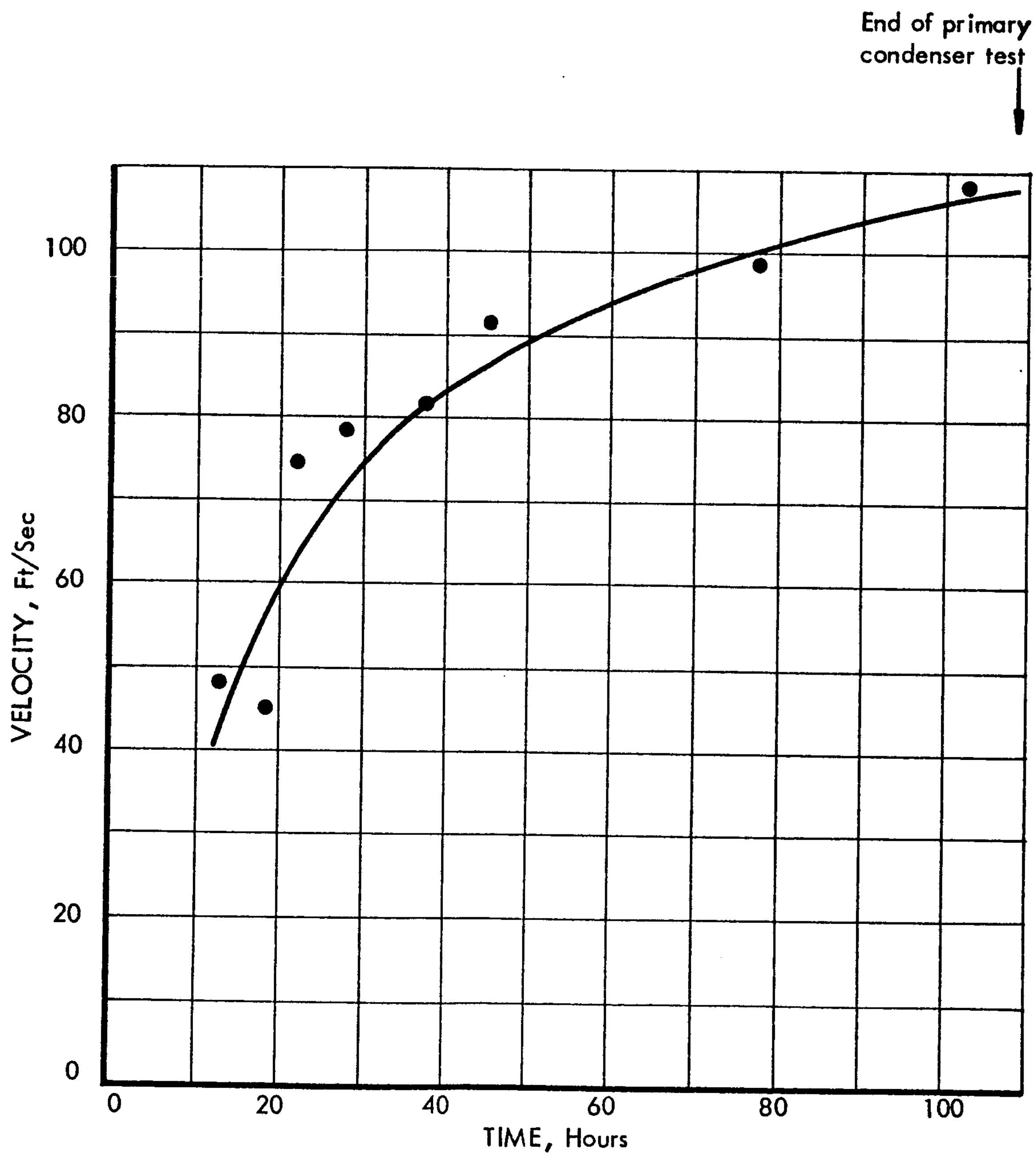


FIGURE 9

TABLE 1

SUMMARY OF TEST GROUP 11 (ARGON)

Material	Furnace Atmosphere	Capsule Number	Cleaning Method	Insert	Barrier	Test Time, Hours	Mode of Corrosion	Depth of Corrosion Mils	LiH Before Test %	LiH After Test %
Haynes Alloy No. 25	Argon	286	C	Haynes Alloy No. 25	Al_2O_3	2500	Capsule - Pitting	0.5	98.5	5.2
							Insert - Pitting	1.0		
Haynes Alloy No. 25	Argon	287	C	Haynes Alloy No. 25	Al_2O_3	2500	Capsule - Pitting	0.5	98.5	4.2
							Insert - Intergranular Depletion	2.0 1.5		
Haynes Alloy No. 25	Argon	288	C	Haynes Alloy No. 25	Al_2O_3	2500	Capsule - Pitting	0.5	98.5	2.7
							Insert - Massive Particle Removal	0.7		
Haynes Alloy No. 25	Argon	289	C	None	Al_2O_3	2500	General Dissolution	0.5	98.5	3.0
Haynes Alloy No. 25	Argon	290	C	None	Al_2O_3	2500	Crevice	0.7	98.5	2.2
Haynes Alloy No. 25	Argon	291	C	None	Al_2O_3	2500	General Dissolution	0.5	98.5	2.5
Haynes Alloy No. 25	Argon	292	C	None	Al_2O_3	2500	General Dissolution	0.5	98.5	2.8
Haynes Alloy No. 25	Argon	293	C	Haynes Alloy No. 25	Solaramic 5210-2C	2500	Capsule - Intergranular	2.7	98.5	84.9
							Insert - Intergranular	1.7		
Haynes Alloy No. 25	Argon	294	C	Haynes Alloy No. 25	Solaramic 5210-2C	2500	Capsule - Leach	4.0	98.5	87.3
							Insert - Pitting, Particle Removal	1.0		

TABLE 2

SUMMARY OF TEST GROUP 11 (ARGON)

Material	Furnace Atmosphere	Capsule Number	Cleaning Method	Insert	Barrier	Test Time, Hours	Mode of Corrosion	Depth of Corrosion Mils	LiH Before Test %	LiH After Test %	Remarks
Haynes Alloy No. 25	Argon	295	C	Haynes Alloy No. 25	Solaramic 5210-2C	2500	Capsule - Intergranular Insert - Intergranular	2.2 1.0	98.5	85.2	
Haynes Alloy No. 25	Argon	296	C	None	Solaramic	2500	Intergranular Leach	2.0 1.0	98.5	75.9	
Haynes Alloy No. 25	Argon	297	C	None	Solaramic	2500	Intergranular Leach	2.7 2.0	98.5	62.3	
Haynes Alloy No. 25	Argon	298	C	None	Solaramic	2500	Intergranular	2.2	98.5	86.0	
Haynes Alloy No. 25	Argon	299	C	None	Solaramic	2500	Leach	4.4	98.5	89.9	Two coats of Solaramic
Haynes Alloy No. 25	Argon	300	C	Haynes Alloy No. 25	Chromallize (XP11121VC)	2500	Capsule - Intergranular Insert - Dissolution	1.5 1.0	98.5	6.8	
Haynes Alloy No. 25	Argon	301	C	Haynes Alloy No. 25	Chromallize	2500	Capsule - Dissolution Insert - Intergranular	0.5 1.5	98.5	16.9	
Haynes Alloy No. 25	Argon	302	C	Haynes Alloy No. 25	Chromallize	2500	Capsule - Dissolution Insert - Dissolution	0.5 1.0	98.5	4.0	
Haynes Alloy No. 25	Argon	303	C	None	Chromallize	2500	Leach	1.0	98.5	2.8	
Haynes Alloy No. 25	Argon	304	C	None	Chromallize	2500	Dissolution	0.7	98.5	3.7	
Haynes Alloy No. 25	Argon	305	C	None	Chromallize	2500	Leach	0.5	98.5	2.7	
Haynes Alloy No. 25	Argon	306	C	None	Chromallize	2500	Leach	1.0	98.5	2.6	

TABLE 3

SUMMARY OF TEST GROUP H-7 (HYDROGEN)

Material	Furnace Atmosphere	Capsule Number	Cleaning Method	Insert	Barrier	Test Time, Hours	Mode of Corrosion	Depth of Corrosion Mils	LiH Before Test %	LiH After Test %
Type 347 SS	Hydrogen	109	C	None	None	4786	Intergranular Depletion	2.5 4.0	98.5	69.7
Type 316 SS	Hydrogen	114	C	None	None	4808	Intergranular Depletion	3.5 5.0	98.5	74.2
Haynes Alloy No. 25	Hydrogen	118	C	None	None	4808	Crevice	1.0	98.5	74.5
Molybdenum	Hydrogen	273	C	None	None	2826	None	-	98.5	88.5

TABLE 4

SUMMARY OF TEST GROUP ST-7

Material	Capsule Number	Cleaning Method	Corrosion Medium	External Atmosphere	Test Time, Hours	Mode of Corrosion	Depth of Corrosion Mils	LiH Before Test %	LiH After Test %	Temp. °F
Haynes Alloy No. 25	283	C	Lithium	Argon	2264.5	Intergranular	1.1	0.0	2.0	1600
Haynes Alloy No. 25	284	C	*Li & LiH	Argon	2264.5	Intergranular	1.0	98.5	3.0	1600
Haynes Alloy No. 25	285	C	LiH	Hydrogen	2264.5	Crevice	0.5	98.5	75.5	1600

* LiH at beginning of test. Concentration of LiH decreased during the test.

A molybdenum sample was run for 2800 hours in the same hydrogen furnace. The significant results of this test are the depth of corrosion encountered in the various materials. It should be noted that molybdenum exhibited the best corrosion resistance in that no noticeable penetration was observed. Haynes alloy No. 25 experienced approximately 1 mil of crevice-type corrosion over a period of 4800 hours. The major significance of the test is the continuing indication that corrosion per se is not an appreciable problem in the one year lithium hydride container.

The results of static tests are presented in Table 4. This test was designed to evaluate the difference between the corrosiveness of lithium, lithium + lithium hydride, and lithium hydride.

A test designed to evaluate the effectiveness of additives in reducing the lithium hydride dissociation pressure was also completed. Preliminary results of this test are shown in Table 5. The results indicate that lithium floride and lithium chloride mixtures with lithium hydride in concentrations from 1 to 40% did not produce a reduction in the loss of hydrogen.

Work is continuing on the construction of the work horse loop. A slight delay was encountered in the fabrication of this loop because receipt of the Haynes No. 25 material was approximately one month behind schedule. The loop is now in the final stages of fabrication. Checkout testing of the loop is scheduled for the latter part of September.

Additional glass coatings have been tested in the hydrogen permeability test rig with results quite similar to those reported earlier for the solaramic coatings. It has been our experience that the tests involving glass coatings consistently show the hydrogen permeation limited to approximately 2.5×10^{2} cc / cm^{2}-hr. / $mm^{1/2}$. On this basis it appears that the commercial glass coatings are reasonably comparable in performance and that the final selection of the coatings will be governed by the ability of the coating to withstand the thermal conditions imposed by the sun-shade cycling.

TABLE 5

SUMMARY OF LiH WITH DISSOCIATION INHIBITORS

Material	Capsule Number	Corrosive Medium, % By Weight	External Atmosphere	Test Time, Hours	Mode of Corrosion	Depth of Corrosion Mils	Initial LiH Remaining After Test, %	Temperature °F	Remarks
Type 316 SS	307	LiH	Argon	171	-	-	14.0	1450-1600	
Type 316 SS	308	99% LiH - 1% LiF	Argon	171	-	-	13.5	1450-1600	
Type 316 SS	309	95% LiH - 5% LiF	Argon	171	-	-	14.3	1450-1600	
Type 316 SS	310	90% LiH - 10% LiF	Argon	171	-	-	17.9	1450-1600	
Type 316 SS	311	LiH	Argon	168	Crevice	1.0	23.2	1600	
Type 316 SS	312	83.3% LiH - 16.7% LiF	Argon	168	Crevice	1.0	24.4	1600	Oxidized
Type 316 SS	313	76.9% LiH - 23.1% LiF	Argon	168	Crevice	1.0	51.7	1600	Oxidized
Type 316 SS	314	71.4% LiH - 28.6% LiF	Argon	168	Crevice	1.0	40.0	1600	Oxidized
Type 316 SS	315	99% LiH - 1% LiF	Argon	168	Pitting	0.5	12.9	1600	
Type 316 SS	316	95% LiH - 5% LiF	Argon	168	Intergranular	1.0	13.6	1600	
Type 316 SS	317	90% LiH - 10% LiF	Argon	168	Intergranular	2.0	11.8	1600	
Type 316 SS	318	60% LiH - 40% LiF	Argon	168	Intergranular	1.0	15.6	1600	
Type 316 SS	325	LiH	Argon	500	Crevice	1.0	16.1	1600	
Type 316 SS	326	80% LiH - 20% LiF	Argon	500	Crevice	1.0	13.5	1600	
Type 316 SS	327	70% LiH - 30% LiF	Argon	500	Crevice	1.0	11.8	1600	
Type 316 SS	328	60% LiH - 40% LiF	Argon	500	Pitting	1.5	17.4	1600	
Type 316 SS	329	LiH	Argon	170	Pitting	0.5	17.1	1600	
Type 316 SS	330	99% LiH - 1.0% LiCl	Argon	170	Pitting	0.8	14.6	1600	
Type 316 SS	331	95% LiH - 5.0% LiCl	Argon	170	Pitting	1.0	16.0	1600	
Type 316 SS	332	90% LiH - 10.0% LiCl	Argon	170	Crevice	0.5	15.6	1600	
Type 316 SS	345	LiH	Argon	500	Leach Intergranular	7.0 1.0	3.9	1600	Capsule Coated - Al_2O_3
Type 316 SS	346	80% LiH - 20% LiF	Argon	500	Leach Intergranular	8.3 1.0	4.7	1600	Capsule Coated - Al_2O_3
Type 316 SS	347	70% LiH - 30% LiF	Argon	500	Leach Intergranular	6.6 2.0	5.8	1600	Capsule Coated - Al_2O_3
Type 316 SS	348	60% LiH - 40% LiF	Argon	500	Leach Intergranular	8.0 1.5	6.7	1600	Capsule Coated - Al_2O_3

IV. CURRENT PROBLEM AREAS

Initiation of system testing in the system test rig has been delayed because the manpower was applied to the CSU I-3 endurance test which also prevented access to the auxiliary booth to install the PCS support equipment. Additional tasks remain of installing and checking out heaters, instrumentation, and the support equipment associated with the PCS I-1 test. As soon as post-test calibrations of the turbo-alternator component rig have been completed, the manpower will be shifted and completion of the system test rig will be expedited.

Although the demonstrated endurance capability of the CSU has been greatly advanced by the recent endurance test, the problems associated with the nozzle corrosion product restrictions need to be corrected. The exact deposition phenomenon is not completely understood; however, precautionary steps are being taken, such as the incorporation of corrosion product separators in the test rig and plans for preconditioning the system to keep the corrosion product formation to the minimum level possible.

Evaluation of the CSC I-1A condenser test has indicated an off-design situation. The condenser section of this report describes in more detail the exact symptoms. However, the net effect will be one of operating the system at a reduced turbine flow in order to allow the CSU to operate at the correct back-pressure conditions. This will cause a reduced power output from the system. The extent of this problem will be evaluated during system testing.

V. PLANNED DIRECTION OF EFFORT FOR THE NEXT QUARTER

Performance checkout and endurance testing of turbo-alternator units will be conducted in the component test booth as dictated by availability of component hardware.

Initial system flushing and checkout testing will be initiated in the systems test booth. The objectives of the tests will be to obtain operating performance data of all components assembled as a system.

After short-term performance testing has been accomplished, other test objectives, including endurance testing, will be achieved.

Single panel solar collector testing will be conducted to determine single panel efficiencies with laquered, vapor-deposited aluminum, and silicon oxide coatings.

Vibration testing of the full-scale preprototype collector with a simulated structure will be conducted on the MB-210 vibration test equipment. Deployment testing of the full-scale collector will be conducted with preprototype rim locking hardware.

Loop testing efforts will consist of completion of the work horse loop and loop checkout. Initial testing will be conducted on the hydrogen swallowing capability of the jet centrifugal pump.

Work will continue on the fabrication of the mercury corrosion loops which are to be operated for 5000 hours. Materials choices are to be Haynes Alloy No. 25 and Croloy 9M.

Materials efforts will consist of the evaluation of capsules currently undergoing test, fabrication of new capsules, and completion of the construction of a second static temperature test furnace.

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